A review of the “Aquatic Properly Functioning Matrix – a condition for the landscape which has been determined to be properly functioning in order to meet the habitat needs of anadromous salmonids and other aquatic species on PALCO properties in Humboldt Co.”

by

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Dr. Larry Marshall, a stock assessment biologist and A/ Manager of the Diadromous Fish Division, holds B.Sc.(Agr), Zoology (1966) and MSc, Fishery Science (1968) degrees from the University of Guelph, Guelph, ON and a Ph.D., Fishery Science (1973) degree from Colorado State University, Ft. Collins, CO. Prior to 1973, when he joined Fisheries and Oceans to work on Atlantic salmon, Dr. Marshall had extensive experience with stream populations of trout in southern Ontario and in the State of Colorado, and surveys of fishes in Lake Huron and in lakes of Saskatchewan.

Over the past 27 years, Dr. Marshall has assessed the status of salmon in many Maritime rivers inc. the Miramichi and Saint John in New Brunswick and Margaree and Saint Mary's in Nova Scotia. During the last 15 years his responsibilities have been focused on salmon of the Saint John River, on which he has published several scientific papers, conducted numerous studies and has, since 1983, annually conducted and authored the Saint John River salmon assessments for the Canadian Atlantic Fisheries Scientific Advisory Committee and Canadian Stock Assessment Secretariat. Since 1995 he has as well assessed and documented the status of salmon in rivers of Cape Breton Island, Nova Scotia. Other responsibilities have included being regional core member of the Anadromous, Catadromous, Freshwater Fisheries Subcommittee of CAFSAC, 1979-93, inc. Chairman, 1986-89, and Regional representative on the International Council for Exploration of the Seas (ICES) Study and Working groups on North Atlantic Salmon, 1981-present. In 1993 and 1994 he was invited to participate in a U.S. Task Force to review the Atlantic salmon restoration efforts in New England, and in 1996 and 1999, respectively, was chosen by peer scientists to Chair the ICES Working Group on North Atlantic Salmon, 1997-1999, and the EIFAC/ICES Working Group on Eels in 2000.

In keeping with the terms of the contract, i.e., “the report produced must be based on the consultant’s individual opinions of the science in his area of expertise…”, commentary is weighted towards salmonids and their habitat.

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EXECUTIVE SUMMARY

In March 1997, U.S. federal and state agencies developed an aquatic matrix for the Pacific Lumber Company Habitat Conservation Plan (hereafter "salmon matrix"). The salmon matrix puts forth a condition for the landscape which has been determined to be properly functioning in order to meet the habitat needs of anadromous salmonids and other aquatic species in northern California, and in particular on Pacific Lumber Company properties in Humboldt County. Since that date, the salmon matrix (and Habitat Conservation Plan) has been the subject of documented and voiced criticism. Critiques have questioned the relative importance of the prescribed metrics, the correctness of their assigned values, and pointed to the difficulty in viewing the sum total of fixed values as an interrelated, interdependent, and in total, a "functioning system".

The salmon matrix is described by its' authors as a "work in action" and as such presents, with some few exceptions, a reasonably complete list of metrics important to the description of salmonid habitat. The prescribed numerics (what is this?) for properly functioning habitat reflect those available at the time of writing but are heavily reliant on assumed transportability (?) of published material derived in more northerly Douglas-fir coastal forests underlain by more structured geological formations. Emerging evidence from northern California redwood forests, that are underlain by a number of unstructured geological formations, suggests that some prescribed values may be inappropriate. More recent thoughts on habitat management, however, prescribe the maintenance of a full range of aquatic and riparian conditions generated by natural disturbance events. That philosophy recognizes that streams are dynamic, watershed processes and effects are cumulative, and that the establishment of fixed habitat standards for various parameters as is done in the matrix is not likely to protect the overall capacity of watersheds to produce fish or recover from natural or anthropogenic disturbances.

The issue of what parameters are best for assessing habitat of the candidate salmonids is resolved by utilizing biological parameters of the targeted species. Measures of juvenile densities and numbers of out-migrants, egg-to-fry and juvenile-to-various stage survival, and growth compared to "norms" are much simpler analyses and represent an absolute measure of progress towards the overall objective. These measures in key watersheds and various stream orders, combined with a watershed inventory of physical parameters, old and new aerial photography and watershed analyses, have the potential of identifying source watershed scale processes and upslope problem areas. The process of amelioration, or reducing the risk of another occurrence in another basin, should be presented to the landowner as "adaptive management", and as such should emphasize flexibility in allowing alternate approaches for achieving biological goals in a manner that is sensitive to both economic concerns and biological necessities. This process offers more incentive for responsible stewardship, something that is less likely to occur when the landowner is forced to address individual parameters which might never have been "properly functioning" for decades. This type of adaptive management actually epitomizes process-based management, facilitating responsible prioritization of the physical indicators/ parameters most in need of attention.

Recommendations for the encouragement of responsible landowner stewardship include:

1. Abandon the "species habitat needs matrix" as a prescription for the needs of aquatic species (The sentence sounds too reflexive; can it be reworded?).

2. Prescribe biological objectives and measures for candidate aquatic species; this goal would normally be evaluated through measures or estimates of, egg-to-fry survival, resultant juvenile densities, and juvenile-to-smolt survival, among other estimates., and it would be expected to vary according watershed size stream order and habitat quality

3. Repackage the matrix pathways/indicators/metrics as a narrative with table(s) and distributions of values (and caveats where necessary) relevant to achieving associated biological objectives; provide a narrative on linkages and examples of how an inventory of metrics and their numerics might be instructive to adaptive management.

4. Promote water quality monitoring, habitat access and key habitat elements (What is this?), particularly "fines" and the maintenance and systematic updating of an inventory of values for all tabled metrics (I don't understand this recommendation).

5. Promote the concept of process-based management in watersheds that suffer impacts from multiple activities (resulting in cumulative watershed effects), facilitating landowner stewardship that works towards improvements and corrections in such source areas.

6. Promote the concept of adaptive management in response to biological parameters, providing examples to landowners on metrics inventory and how their values could benefit either the candidate species or themselves.

7. Promote landowner stewardship and partnerships in Endangered Species Act Recovery Plans to assess numbers of spawning salmonids and out-migrant smolts. This would permit a total evaluation of landscape effects on freshwater production and survival relative to estuarial and marine survival, and it could possibly result in a more positive public image for the landowner.

INTRODUCTION

Background

In March 1997, U.S. federal and state agencies tabled an aquatic matrix (Appendix I) for the Pacific Lumber Company Habitat Conservation Plan (hereafter "salmon matrix"). The salmon matrix puts forth a condition for the landscape which has been determined to be properly functioning in order to meet the habitat needs of anadromous salmonids and other aquatic species in northern California, and in particular on Pacific Lumber Company (PALCO) properties in Humboldt County. The purpose of the matrix was to establish a "yardstick" against which to measure "baseline conditions" and "assess the extent to which conditions must improve" (Condon pers comm).

Since March 1997, the salmon matrix (and Habitat Conservation Plan) has been the subject of documented (USFWS 2000; Public/Private Comments: PART III: Other documents) and voiced (to this panel) criticism. This stems in part from inherent limitations recognized by then developers/contributors B. Condon (pers comm) and S. Kramer (pers comm) and others. Limitations (Are these limitations based on the reviewer's opinion or those that are cited by the literature and critics?) include:

- The matrix is based on the best available scientific information at the time of writing but does not include a procedure by which it can be updated.

- Some of the pathways and narrative or numeric indicators are based on information derived from studies conducted outside the redwood region and frequently do not account for conditions unique to certain geologic formations within PALCO holdings.

- The target values collectively represent a "snap shot", and most do not account for temporal and spatial variability in stream habitat

- The matrix characterizes stream conditions described in "unmanaged" coastal, late-successional and old-growth forest ecosystems. These seral stages of forest community succession actually represent a large range of conditions, especially when the variability in disturbance regimes is considered.

- The matrix describes conditions expected to be achieved and maintained during the life of the habitat conservation plan, but the "life" is defined by the applicant (who is the applicant? PALCO?) and is usually too short to meet stated objectives.

- Failure to include more biological indicators as measures of properly functioning conditions.

In an effort to resolve the debate surrounding the utility of the salmon matrix, the National Marine Fishery Service (NMFS) requested that the University of Miami's Center for Independent Experts (CIE) organize an independent peer review of the proposed plan. Five panel members were contracted in late 2000, and arrangements were finalized for a four-day meeting between the members and NMFS officials in Arcata, California, from November 27-30, 2000. Panel members were also provided with a copy of the salmon matrix and related literature (listed as part of Appendix II).

Statement of Work

The original (Statement of Work) dated October 20, 2000, appear in Appendix IIIa. An "Addendum to the Statement of Work" ,dated November 22, was provided to panel members in Arcata, November 29, 2000, "to clarify some of the questions that the reviewers are to address when conducting the review and completing the report" (Appendix IIIb).

Panel Membership

The five-member panel consisted of the following experts:

Dr. Mike Bradford, Fisheries Scientist, Department of Fisheries and Oceans, Habitat and Enhancement Branch, Burnaby, BC Canada;.

Dr. Rick Cunjak, Professor and Salmonid Ethologist, Department of Biology, University of New Brunswick, Fredericton, NB Canada;

Dr. Larry Marshall, Biologist, Diadromous Fish DivisionScience Branch, Maritimes Region Bedford Institute of Oceanography, Dartmouth, NC, Canada.

Dr. Richard Marston, Professor, School of Geology, Oklahoma State University, Stillwater, OK, USA; and,

Dr. Chris Soulsby, Professor of Hydrology, Department of Geography and Environment, University of Aberdeen, Aberdeen, Scotland.

Description of Panel Review Activities

Panel members convened on Monday, November 27 through Thursday, November 30, at the NMFS offices in Arcata, CA. NMFS staff member, John P. Clancy, provided the agenda for the first day and a list of "Additional Information Resources" (Appendix IV). John offered many additionally helpful suggestions, and at the request of the Panel, made and participated in all subsequent arrangements, including meetings with local experts and three half-day field trips to view pristine, impacted, and severely-impacted watersheds.

Monday Nov 27, presentations by:

Greg Bryant, Salmonid Recovery Coordinator, NMFS. "Regional salmonid species status".

John P. Clancy, PALCO HCP Implementation, NMFS. "Structure of the PALCO HCP".

Bill Condon, PALCO HCP Implementation CA Dept. Fish & Game. "Development and role of Matrix in the PALCO HCP".

Bill Trush, Fish Biologist/Fluvial Geomorphologist, McBain and Trush. "Sediment and turbidity regimes in disturbed vs. undisturbed local watersheds" and "Effects of sediment and turbidity on salmonid growth and survival"

Sam Flanagan, Geologist, NMFS. "Description of local geology and resulting stream channel form and function"

Randy Kline, Hydrologist, National Parks Service. "Local large woody debris surveys and stream channel function" and "Discussion of what are the best indicators of salmonid health habitat"

“JB” and John Peters of NMFS also contributed points of clarification /discussion.

Tuesday Nov 28

Randy Kline, Hydrologist, NPS and Ethan Bell, Stream Ecologist, Stillwater Sciences, led the Panel, “JB” and John Clancy on a tour of 3 sites on Prairie Creek, a small relatively undisturbed catchment in Redwood National Park. Points of interest included a turbidity and suspended sediment gauging station in operation since 1989, old-growth redwoods, stream terraces, quality habitat for coho and chinook salmon, and an example of large woody debris and pool formation.

The afternoon was used in reviewing materials and collectively developing a plan for Wednesday.

Wednesday Nov 29, presentations and discussion by

Mary Ann Madej, Geologist, USGS/Biological Resources Division, who provided an overview of her work on time and spatial scales in the understanding of channel change, esp., her work on Redwood Creek .

Sharon Kramer, Fish Biologist, Stillwater Sciences, and one of the primary contributors to development of the “salmon matrix”. She emphasized that the matrix is an adaptation of an existing framework which generalized for whole drainages, lacked spatial/ temporal indicators and linkages, and included much data from areas outside of northern California.

The Panel, led by John Clancy was then transported to view lower reaches and licensed gravel mining areas on the Eel River. Examples of significant aggredation resultant of landslides in recent (1995-96) and past (1955 and 1964) years were shown on Jordan, Bear and Cuneo (at confluence with Bull) creeks of the Eel and South Fork Eel rivers, proximate to the “Avenue of Giants”. Rain over night and still intermittent, yielded gray-colored water presumably high in suspended solids.

Thursday, Nov 30

Nick Dusseach, Forest/Road Engineer and Matt House, Aquatic Resource Engineer for Simpson Timber Company (Arcata Redwood Company, Korbel, CA) led the Panel inc. John Clancy, and fellow NMFS HCP workers Alice and Gareth on a tour of road culverts due for replacement or recently replaced on Simpson lands. The Simpson employees described a family-owned Company systematically reducing the risk of road wash-outs and stream sediment loading through the use of larger connect and new disconnect culverts at their many crossings. They as well showed a site in which an older culvert was upgraded to a bridge crossing capable of withstanding 100-year floods and which provided improved upstream access for salmonids. Matt indicated Simpson’s involvement in baseline channel monitoring and in 2-stage sampling of juvenile salmonids for determination of densities, both of which were viewed as responsibilities background to adaptive management.

Leslie Reid, Research Geomorphologist, USDA-Forest Service, addressed the panel on her work on cumulative watershed effects particularly in the Casper Creek Experimental Watershed, Mendocino County, CA, and in the Waipaoa watershed, New Zealand.

Sam Flannigan, Geologist, NMFS, elaborated on on-going watershed analyses of PALCO holdings.

Description of Individual Review Activities

In keeping with the terms of the contract., “the report produced must be based on the consultant’s individual opinions of the science in his area of expertise…”, commentary was weighted towards the salmonids that are to occupy the “properly functioning habitat”. Little time was spent reviewing literature background to or values transported (what does this mean?) to the matrix. Most pre-panel effort focused on the matrix per se, and reviewing post-matrix reviews and documents provided in the “related literature”. Additional readings focused on literature published after the matrix, specifically in the fisheries journals “Canadian Journal of Fisheries and Aquatic Sciences” and “Fisheries”. The intent was not to conduct a comprehensive literature review but rather to target two journals with which this reviewer was familiar in order to determine whether recent articles, particularly those related to fisheries habitat management, echoed the opinions of local experts (including those who made presentations to the panel).

The “findings” are presented as direct, terse responses to questions 1 through 4 in the Statement of Work (Appendixes IIIa and IIIb). The answers to questions 1, and 2, are brief because many of the metrics and proposed values for properly functioning habitat are outside this reviewer’s area of expertise; moreover, these metric, in summary analyses, are considered to be of less importance than proposed biological parameters for direct measure of properly functioning habitat. The responses to questions 3 and 4 are also brief because the matrix, in its’ attempt to make streams conform to an idealized notion of optimum habitat through legal regulations or channel manipulations, appears to i) overlook the processes which contribute to the state of the habitat and ii) effectively stifles adaptive management and responsible landowner stewardship.

Acknowledgments

Special thanks are extended to John Clancy, NMFS, who served as the host to the panel during its stay in Arcata. John gave freely of his professional and personal time, organized the opening day, provided a cross section of valuable information for panel members to digest, and cheerfully made all possible subsequent arrangements requested by the panel. Considering the criticism that appears to have enveloped the matrix since 1997, John presented all information and resource persons in a professional, objective, and impartial fashion. I also extend thanks to all federal, state, and non-governmental organization (NGO) experts, and Simpson Company representatives (listed in the preceding subsection) who provided background information, concerns, new insights, and who presented ongoing research/ management activities on public and private lands. Without their input, the exercise would have been sterile. Finally, I thank my fellow panel members for openly sharing their expertise and ideas.

FINDINGS

Question 1.

Are the metrics used in the matrix appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs for threatened and candidate salmonid species? If not, which metrics would be appropriate and at what landscape scales?

Dissection of the matrix and its nested layers for Class I and II watersheds (What are these?) revealed the following factors as important needs for aquatic species, including salmoinds: Six pathways, 20 “indicators” and 47 parameters or “metrics” (including nested redwood and Douglas-fir criteria within Riparian Buffer) (Table 1). The survival/sustainability of candidate salmonid species is generally linked to the first 6 or 7 parameters (Table 1); the remaining parameters may affectincreased yield. All parameters can be considered appropriate for assessing aquatic and associated riparian habitat conditions, even though some seven or more lack prescribed measures. It is difficult to envision, however,the actual resources necessary to inventory, let alone monitor or improve all parameters across a large landhold. More interestingly, there is no mechanism in the matrix with which to verify that the prescribed values for each of the metrics that would result in more than an “on-paper” functioning system.

Lewis (Public/Private Comments…) observed that “road management” and “hot spots’ are questionable terms for “parameters”; these are among the seven parameters that have no obvious units of measure. Further, “road management” is a rather nebulous term to capture upslope processes in part controlled by capacities of culverts and bridges. The potential impact of landslides, their size, and growth - as documented from aerial photography -should be included in the inventory requirements. While winter refugia are given consideration in “conditions for pool habitat”, (Lewis *op cit*) and possibly in “off-channel habitat”, winter habitat, per se, is ignored as an “indicator”. Also ignored are those combined metrics which comprise “spawning habitat” or holding pools for returning adults, (substrate, water depth, water velocity and stream width) for species such as California golden trout (Knapp and Preisler 1999),.. In fact, metrics concerning the important habitat functions, such as adult holding, spawning, juvenile rearing, and over-wintering, should be addressed individually. Kline (personal communication) also noted that suspended solids, ideally measured with turbidity at gauging stations was as well not specifically mentioned (Does this mean that suspended solids or turbidity should be considered as a metric/parameter?).

The lowering ranking of flow/hydrology in the matrix appears to undermine the importance of in-stream flows as the “real” pathway (Table 1). It would seem that to in order to be of full utility, discharge values should indicate the following:

a) minima and possibly maxima in which juveniles of target salmonid species are typically found in summer and winter, and;
b) minima and possibly maxima in which adults of target salmonid species typically hold (What does this mean?), spawn and over-winter.

The inclusion of in-stream flows as a pathway would also better facilitate the definition of potential Class 1 waters for salmonids, especially in those where salmonids may be absent due to low stock status or physical/chemical barriers. The inclusion could also help identify the potential for restoration activities.

The forgoing(?) criticisms pale in comparison to the observation that linkages to measures of current biological production, the underlying and most important measure of a “properly functioning system”, are omitted (The only current clear connection between salmonids and a matrix metric is “temperature” [lethal and preferred values]; thereafter inference to the importance of the various parameters and their values to salmonids is restricted to brief qualitative narratives under “Biological impact/concern” in Attachments B and D.). Thus, the matrix as a “condition for the landscape” would be significantly more meaningful with the establishment of direct and assessable links between physical attributes and resultant biological production. Without such links, it is questionable that the matrix is the appropriate prescription for forested landholders. A narrative with generalized diagrams of pathways (e.g., Beechie and Bolton 1999) and the relationship to biological production would be more understandable. The matrix itself could then be reduced to a table of metrics (with distributions of numerics) important to factors such as adult migration, spawning, egg-to-fry survival, fry-to-various stages of juveniles, over-winter survival of juveniles, emigration of the candidate salmonids. The envisioned format would not in fact differ dramatically from the Fish and Aquatic Habitat section within the Headwaters Final EIS/EIR (USFWS 1999) or the more concise overview of the PACFISH Strategy (Williams and Williams 1997) (without the condition that listed management objectives must be met or exceeded)- What does this mean? Does it refer to the other two strategies, or is it recommending that the condition be removed from the matrix?.

Biological parameters useful to the proposed process include juvenile densities of target salmonids, calibrated to estimated spawning escapements/egg depositions. Such measures would, because of experimental error and annual variability, increase in utility as the database grew - a minimum time period should be at least three years. Measures of abundance across drainages of various sizes/ streams of different order (most likely 3rd, 4th or possibly 5th order) would also reflect measures of the important cumulative effects (Reid 1998). Additionally, these measures could offer immediate openings to discussions on adaptive management, and with key habitat monitoring, possibly a start at process-based management (Beechie and Bolton 2000, see Question 4). (REWORD)

Additional biological metrics complimentary to juvenile densities are:

a) Egg-to-fry survival (first winter) which is most easily evaluated by the use of "egg baskets" (containers filled with washed gravel and a known numbers of eggs and placed in artificial redds for subsequent removal and determination of development, hatch rates, and accumulation of fines), or fry traps placed over redds which contain known or estimated numbers of eggs;
b) Juvenil length frequency data for evaluation against optimal growth;
c) Smolt/ out-migrant counts that permit the assessment of juvenile-to-smolt survival (second winter).
d) Numbers of smolts leaving the estuary and adults returning to the river would be invaluable in providing the basics of a complete stock assessment and identifying deficiencies of freshwater, estuarine, and marine survival.

Question 2.

Are the values provided for the metrics appropriate for assessing aquatic and associated riparian habitat condition to meet the needs of threatened and candidate salmonid species in coastal redwood systems? If not, which values would be appropriate and at what landscape scales?

For several reasons it seems moot to critique the appropriateness of the individual values proposed for the physical parameters:

- Following from the first question, there is relatively greater value in considering biological parameters and their numerics than focusing on the values already researched for physical parameters, particularly since biological values should yield information on the more important, local, cumulative watershed effects.

- Consideration of cumulative watershed effects on biological production minimizes the importance of the precision of the mostly transported (What does this mean?) literature values for individual parameters.

- The target values for habitat collectively represent a "snap shot". Most values do not account for temporal and spatial variability in stream habitat, instead presenting a provision of target values that imply that "one size fits all" when appropriate values with resulting immeasurable differences in biological production may lie within a distribution of values. It would thus seem more appropriate to provide distributions of values and, where possible, associated probabilities of the values that are effective in optimizing salmonid survival, growth, densities, among other results, in freshwater.

- Values were, by and large, based on the best scientific information available in late 1996 and early 1997. Values, especially those derived locally and presented recently (Madej 1999; Ziemer 1998; Taylor 1999, and Prager et al. 1999) and those values documented by critics (e.g., Lewis and Montgomery IN Public/Private Comments…) require consideration, andlocal experts would be more proficient in assessing their appropriateness.

- Some of the numerics are based on information derived from studies conducted outside the redwood region and frequently do not account for conditions unique to certain geologic formations within PALCO holdings, i.e., these values should be clearly identified as proximate, rather than precise.

- Characterizing stream conditions as “unmanaged”, coastal, late-successional and old-growth forest ecosystems actually represents a large range of conditions and as such should be identified.

Collectively, the preceding points suggest that the inferred precision of the prescribed target values for local temporal and spatial variability in stream habitat is somewhat tenuous. Values should be qualified, updated, and broadened to account for the changing physical dynamics in stream units associated with biological production. However, Bisson et al. (1997) caution against attempts to establish fixed habitat numerics for parameters such as those provided in the matrix, as they are unlikely to protect the overall capacity of watersheds to produce fish or to recover from natural or anthropogenic disturbances. Rather, Bisson et al. contend that it is better to focus on maintaining the full range of aquatic and riparian conditions generated by natural disturbance events at large landscape scales. Attempts to make streams conform to an idealized notion of optimum habitat through legal regulations or channel manipulations will not easily accommodate cycles of disturbances and recovery, and it may lead to long-term habitat and bio-diversity losses.

Ranges of summer densities of juvenile coho and chinook salmon and steelhead and cutthroat trout or respective smolt production for different sized drainages/ stream orders etc., have not been researched by this reviewer. However, It is hypothesized that the abundant west coast salmonid literature (e.g., Bradford 1997; Rosenfeld et al. 2000), would with stage-specific survival values, yield “norms” for densities in pools, flats and riffles, either singly or in combination against which sample density and survival data could be evaluated. Data from local drainages that are relatively unimpacted (e.g., Prairie Creek, Casper Creek) or somewhat impacted by forest practices (e.g., Little River) could be used for verification of transported norms or for establishment of local norms. As stated previously, measures of either density or production per unit area/stream length will provide a simplified evaluation on how “properly” the system is functioning.

Question 3.

Which metrics are the most appropriate for the assessment, monitoring, and adaptive management of aquatic candidate salmonid species in coastal redwood systems?

In the absence of candidate salmonid species in Class I or potential Class I waters, the most appropriate metrics for assessment and monitoring are in-stream flows, temperature (lethal, preferred and MWAT (What does MWAT stand for?)) turbidity/ sediment (suspended solids), water free of lethal contaminants (herbicides/pesticides) and water courses free of barriers and disturbance history (Table 1). All but the last parameter constitute basic life requirements of salmonids, are easily determined, and can be investigated straightforwardly to ascertain their potential for alteration. The determination of the corrective possibilities would lead, in the simplest sense, to adaptive management, in the way that corrective measures that are practical would be pursued by the landowner, whereas impractical measures would be abandoned. This result would be consistent with the stated purpose of adaptive management, which is to “ensure that the HCP prescriptions are implemented in a manner that reflects sound science, taking into account new data and analysis” while providing “flexibility by allowing alternative approaches for achieving biological goals ……in a manner that is sensitive to both economic concerns and biological necessities” (PALCO HCP).

In the presence of candidate salmonid species in Class I waters, the determination of salmonid juvenile densities (relative to the number of adults contributing to those densities) may represent the best assessment and monitoring "metric" at various points in the watersheds. Additional biological metrics complimentary to juvenile densities include egg-to- fry survival (first winter) and juvenile-to-smolt survival (second winter), although within season "stage-to-survival" values (This sounds awkward; please relocate),would also be useful. Monitoring of these metrics could be readily accomplished in 3rd, 4th and perhaps 5th order streams.. Monitoring and assessing the number of smolts leaving the estuary, as well as the adults returning, are both invaluable metrics that provide the basic measures or stock assessment, while identifying the relative impediments to freshwater, estuarine, and marine survival. Water temperature, turbidity, and especially suspended sediment appear to be key physical metrics for continuous monitoring and assessment. Monitoring of "habitat elements" which are subject to seasonal variability and could affect survival of salmonids(or those metrics couched within "substrate" (Table 1)) may also be required. The remaining 30 or so metrics (Table 1) would be useful for assessment purposes but could, in the absence of significant perturbations, be committed to inventory.

The biological metrics lend themselves to an adaptive management process. For example, juvenile densities that were estimated at a reasonable level of probability to equal a defined "norm" might indicate, upon review of the tabled physical inventoried values, that some riparian values in the assessed situation, were over-prescribed for "properly functioning habitat" (Reword this sentence; it is very difficult to follow). Thus, some HCP prescriptions might be re-evaluated, leading potentially to the relaxation of stream buffer zones and increased opportunity for forest harvest. The opposite could also be true, such that re-evaluation finds that juvenile-to-smolt survival was below the accepted norm because the slack water habitat being "maintained" for over-winter areas was inadequate, necessitating enhancement by the landowner.

Question 4.

How should in-stream and riparian metrics be functionally and practically linked with upslope and watershed scale processes that, in part, determine their expression? and, Question 2 (Addendum). Does the matrix framework provide adequate tools and guidelines for stream and riparian metrics to be functionally and practically linked with upslope and watershed scale processes that, in part, determine their expression? If not, what additional features, properties, or guidelines should be addressed to the matrix framework?

Critiques have quibbled over the relative importance of the prescribed metrics and the accuracy of their numerics, but the larger part of this criticism has focused on the difficulty in viewing, quantifying and evaluating the sum total of individual, interrelated, and interdependent effects in a "functioning system". The importance of cumulative in-stream "impacts" resulting from riparian/ watershed activities/processes (such as water-related transport of sediment, woody debris, chemicals, heat, flora, or fauna from extant riparian buffer zones) has been discussed elsewhere in the past (Leslie 1998; Naiman et al. 2000) but has not been effectively addressed/linked in the matrix. In part, this is due to the complex interplay and impact of several dozen variables involved in the dynamic process of a properly functioning habitat. Consequently, Bisson et al. (1997) suggest that it is better to focus on maintaining the full range of aquatic and riparian conditions generated by natural disturbance events at large landscape scales rathen than to concentrate on the sum of parameters made to conform to an idealized notion of optimum habitat. Bisson et al. (op cit) also suggest that the desired future condition can be derived by examining how natural disturbances influence the distribution of aquatic habitats and development of riparian communities within relatively pristine watersheds, and then by using these patterns as target conditions for watersheds in which management activities are planned.

The functional and practical link has been alluded to in response to previous questions – utilize metrics for the candidate salmonid species as the measure of total impacts and functionally and practically link the key impact upstream to a logical source (I don't understand this sentence). The biological and physical parameters, as well as the complete list of inventoried metrics, should facilitate in the deduction of important sources and mitigation potential. Any predictive capabilities gained from the analyses would be an important contribution to adaptive management.

An example of a simple linkage between an identified habitat problem and an upslope process might be as follows:
1. Egg baskets are located in which the mortality rate is unusually high and interstitial spaces are filled with fines2. Managers/scientists would evaluate suspended sediment data at gauging stations within the watershed for background and pertubated levels;3. Managers/scientists would conduct watershed analyses using updated inventories and new and old air photos looking for potential, upstream sources, including destabilized banks, road washouts, new or enlarged "slides", and, in the case of the latter, possible contributing factors

The linkages in the oversimplified example above utilize an inventory of upslope metrics, such as culverts/ capacity, bridges, underlying geology, land slides and their dimensions, forest harvest history on various slopes, and others, from new and old air photos. Some of these parameters, as mentioned previously, are not evident on the list of matrix parameters. Also as previously inferred, linkages between a large number of variables are not a prominent feature of the matrix in its nested format. Narratives and schematics (Leslie 1998; Naiman et al. 2000) and biological parameters are again suggested as offering the most effective manner of communicating upslope and watershed processes.

The inclusion of the significant upslope features is fundamental to newer holistic concepts of identifying salmonid habitat-forming processes and their management (Beechie and Bolton 1999). Their (Whose? That of the authors or of the processes?) strategy (Beechie and Bolton op cit) focuses analyses on the historical reconstruction of habitat-forming processes at the watershed scale in order to identify which processes are disrupted, as well as locations and timing of land use effects on those processes. The goal requires that historical reconstruction focus on diagnosing disrupters to processes rather than conditions. This permits identification of restoration actions that may be prioritized on the basis of biological objectives, and contrary to the objectives of the matrix, precludes the impractical objective of having to adjust each of the numerous parameters to a unique and dynamic system. The goal of restoring natural habitat-forming processes shifts managers away from attempts to control processes and allows the natural variation of processes to vary habitat characteristics. In addition, restoring habitat forming processes should recover and sustain conditions for the long term because such processes will maintain habitat conditions without continual management intervention.

RECOMMENDATIONS

The following recommendations shall encourage responsible stewardship on private holdings:

- Abandon the "species habitat needs matrix" as a prescription for the needs of aquatic species.

- Prescribe biological objectives and measures for candidate aquatic species; this goal could be evaluated through measures or estimates of egg-to-fry survival, resultant juvenile densities, and juvenile-to-smolt survivals, among others, and would be expected to vary according watershed size and stream order.

- Repackage the matrix pathways/indicators/metrics as a narrative with table(s) and distributions of values (and caveats where necessary) relevant to the attainment of the biological objectives; provide a narrative on linkages, as well as examples on how an inventory of metrics and their numerics might be instructive to adaptive management.

- Promote water quality monitoring, habitat access and key habitat elements, particularly “fines” and the maintenance and systematic updating of an inventory of values for all tabled metrics.

- Promote the concept of cumulative watershed effects (impacts resulting from multiple activities) and process-based management to promote/facilitate landowners’ stewardship in working towards improvements/corrections in source high-impact effects.

- Promote the concept of adaptive management in response to biological parameters, providing examples of how the landowners’ inventory of metrics and values could benefit either the candidate species or landowner.

- Promote landowner stewardship and partnering in ESA Recovery Plans to assess numbers of spawning salmonids and out-migrant smolts. This would permit total evaluation of landscape effects on freshwater production and survival relative to estuarial and marine survival, and potentially yield a more positive public image for the landowner.

Table 1. Pathways, indicators and metrics (parameters) in the "salmon matrix".

PATHWAY	INDICATOR	METRICS
Water Quality	Temperature	Preferred
		MWAT
	Sediment/Turbidity	Turbidity
		Suspended solids (new)
	Chemical Contamination/ Nutrients	inc. in Clean Water Act
Habitat Access	Physical Barriers	Any
Habitat Elements	Substrate	% Fines < 0.85 mm
		% Particles <6.35 mm
		GM Diameter
		Fredle Index
		V+
		Pebble Count (D50)
		Scour Chains
		Surface Erosion/Mass wasting
		Macroinvertebrate pop'n diversity indices
	Large Woody Debris	GM diam, length, volume & number, varies with channel width
	Pool Frequency, stream grade >=3%; width <10m	Pools per mi equiv to pool to pool spacing based on bfs widths
	Pool Frequency, stream grade <3%; width <=19m	Pools per mi equiv to pool to pool spacing based on bfs widths
	Pool Quality, stream grade >=3%; width <10m	% stream surface area = pool
		% of no. pools assoc with LWD
		Maximum depth
		Volume
		Cover
	Pool Quality, stream grade <3%; width <=19m	% stream surface area = pool
		% of no. pools assoc with LWD
		Maximum depth
		Volume
		Cover
	Off-Channel Habitat	Slack water (maintain: measure?)
	Hot Spots/Refugia	maintain (measurement?)
Channel Conditions & Dynamics	Width/ depth ratio	maintain (measurement?)
	Streambank condition	>90% stable
	Floodplain Connectivity	maintain off channel areas (?)
Flow/ Hydrology	Change in Peak/ Base Flows	measure?
	Increase in Drainage Network	zero/ minimum increase
Watershed Conditions	Road Management	Performance standards (?)
	Disturbance History	??
	Riparian Buffer	(QMD) (/1) of fully stocked stands
		Ave no. large trees/acre (redw // d-f)
		Overstory tree canopy closure
		Ave. tons LOD/acre (redw // d-f)
		Ave. No. large pieces on ground/ acre)redw // d-f)
		% surface cover & undisturbed area
		snags/acre >=0 in dbh
		stream bank stability (qualitative)

APPENDIX I: **Aquatic Properly Functioning Condition Matrix**.

a.k.a. Species Habitat Needs Matrix

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- ☆ The Matrix displays a condition for the landscape which has been determined, using the best scientific information available, to be properly functioning in order to meet the habitat needs of aquatic species.
- ☆ The Matrix below is to be used for Class I and II watercourses; Class III watercourse properly functioning conditions are found in Attachment "F".
- ☆ All indicators are interrelated, may are interdependent, and should be viewed together as a functioning system.

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	REFERENCE	NOTES
Water Quality:	Temperature	11.6-14.6° C (53.2-58.2°F: MWAT 16.8° C (62.2° F) late summer juvenile rearing.		May be lowered to meet amphibian needs. Refer to attachment "A" for information regarding methodology.
	Sediment/Turbidity	Refer to attachment "B" for Class I & I watercourses. Refer to attachment "F" for Class III watercourses		High priority for research and monitoring to adjust for specific geologic formations and soil types

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	REFERENCE	NOTES
	Chemical Contamination/ Nutrients	low levels of chemical contamination from agricultural, Industrial and other sources, no excess nutrients, no CWA 303d designated reaches; complies with Basin Plans	Clean Water Act and state regulations	Being further explored for appropriate verbiage and standard.
Habitat Access:	Physical Barriers	any man-made barriers present in watershed allow upstream and downstream fish passage at all flows		
Habitat Elements:	Substrate	Refer to attachment "B" for D-50, pebble count		
	Large Woody Debris	Refer to attachment "C" for Class I & II watercourses Refer to attachment "F" for Class III watercourses		Conditions for redwood dominated areas is being further explored; preliminary figures will be available soon.
	Pool Frequency	Refer to attachment "D" for pool frequency and attachment "C" for large woody debris		
	Pool quality	Refer to attachment "D" and "C"; pools >1 meter deep, based on minimum residual summer depth (holding pools), with good cover and cool water, minor reduction of poor volume by fine sediment		
	Off-channel Habitat	maintain existing backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.)		

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	REFERENCE	NOTES
	"Hot Spots" and Refugia (Important remnant habitat for sensitive aquatic species)	maintain existing habitat "hot spots" (good habitat in limited areas) and refugia (havens of habitat safety where populations have a high probability of serving periods of adversity) at the macro scale (e.g. intact reaches, drainage, etc.); existing refugia are sufficient in size, number and connectivity to maintain viable populations or sub-populations	USDA 1993 (SAT Report)	
Channel Condition & Dynamics:	Width/Depth Ratio	maintain width/depth ratio in properly functioning streams, as determined by reaching and/or maintaining properly functioning conditions of other parameters; improve width/depth ratio in degraded streams		
	Streambank Condition	>90% stable; i.e. on average, less than 10% of banks are actively eroding		
	Floodplain Connectivity	maintain off-channel areas hydrologically linked to main channel; maintenance of overbank flows, wetland functions, riparian vegetation and succession; restore connectivity where feasible on ownership		
Flow/Hydrology:	Change in Peak/ Base Flows	watershed hydrography indicates peak flow, base flow and flow timing characteristics comparable to an undisturbed watershed of similar size, geology and geography.		

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	REFERENCE	NOTES
	Increase In Drainage Network	zero or minimum increases in drainage network density due to roads; zero increase in volume capacity in natural channels so as not to degrade channel conditions		
Watershed Condition:	Road Management	Entire road network (including permanent, seasonal, temporary and abandoned [legacy] roads, landings and skid trails) are storm-proofed, armored or retired (stream crossings altered so as to prevent erosion, road blocked to prevent motorized use, etc.). All intact road surfaces and drainage facilities and structures receive at least annual inspection and additional inspection during use and wet periods for proper design and function. Proper design and function evaluated according to specific performance standards pertaining to sediment delivery, drainage network density and volume capacity of natural channels. All elements of the road network found, through inspection, to not meet or high probability of not meeting performance standards must be treated, relocated or retired.		
	Disturbance History			Further discussion warranted based on outcome of PalCo's response to SYP comments from agencies

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PATHWAY	INDICATORS	PROPERLY FUNCTIONING	REFERENCE	NOTES
	Riparian Buffer	For specifics refer to attachment "E" for Class I & II watercourses. Refer to attachment "F" for Class III watercourses. The riparian buffer system provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatershed. Includes buffers for known "hot spots" and refugia for sensitive aquatic species; percent similarity of riparian vegetation to the potential natural community/ composition is achieved		

Developed by staff in: National Marine Fisheries Service, Environmental Protection Agency, California Department of Fish and Game, California Department of Forestry and Fire Protection and North Coast Regional Water Quality Control Board

Compiled By: Vicki Campbell, National Marine Fisheries Service

Prepared For: Pacific Lumber Company habitat conservation planning effort

DATA USE AND EVALUATION

For the purposes of water quality assessment and management, temperature data is used to assess impacts on any beneficial water use(s). In the North Coast Region, attention is directed to the temperature requirements of cold water fishery resources, particularly anadromous fish populations, as this beneficial use is extremely sensitive to certain temperature conditions. Wide daily variations of temperatures and elevated water temperatures can cause significant impairment of the successful propagation, rearing and survival of anadromous fish populations.

Regional Water Board staff recommends using two references for evaluating stream temperatures:

Temperature Criteria for Freshwater Fish: Protocol and Procedures published by U.S. EPA in 1977.

Guidance of Evaluating and Recommending Temperatures Regimes to Protect Fish, Instream Flow Information Paper 28, Carl Armour, U.S. Fish and Wildlife Service, 1991.

Maximum Weekly Average Temperature Requirements (MWAT)

The MWAT is the mathematical mean of multiple, equally spaced, daily temperatures over a 7-day consecutive period. A minimum of two data are required to determine the MWAT: the "physiological optimum temperature" (OT) and the "upper ultimate incipient lethal temperature" (UUILT). While the OT can be measured for numerous physiological functions, growth appears to be the most sensitive function. The UUILT is the "breaking point" between the highest temperatures to which an animal can be acclimated and the lowest of the extreme upper temperatures that will kill the organism.

MWAT is calculated as follows:

$$\text{MWAT} = \text{OT} + (\text{UUILT} - \text{OT})/3$$

OT = a reported optimal temperature for the particular life stage or function.

UUILT = the upper temperature that tolerance does not increase with increasing acclimation temperatures.

We have calculated a MWAT for juvenile coho for late summer rearing and found a narrow range for temperatures which are dependent on acclimation temperature:

Acclimation temperature	UUILT	OT	MWAT
15 ° C	24 ° C	13.2 ° C	16.8 ° C
20 ° C	25 ° C	13.2 ° C	17.1 ° C
>23 ° C	25.8 ° C	13.2 ° C	17.4 ° C

The OT is the average of the preferred temperature range which is reported to be 11.8 C to 14.6 C (Reiser and Bjornn, 1979, Influence of Forest and Rangeland Management of Anadromous Fish Habitat in the Western United States and Canada, USDA Forest Service Technical Report PNW-96).

Draft Properly Functioning Conditions for Sediment Levels (3/20/97)

Purpose of table: Identify properly functioning salmonid habitat and other beneficial use target conditions relative to instream sediment levels and hillslope sediment delivery mechanisms on PL ownership. Sediment is one of several water quality and habitat variables used for evaluating watershed health and impacts of management proposals.

Selection of Parameters and Targets: The listed parameters are based on lab and field research conducted throughout the Pacific Northwest (as described in Chapman 1988, Bjornn and Reiser 1991 and others) as well as a limited amount of localized information from Northern California (Knopp 1993, Burns 1970). Baseline data for some of the parameters (e.g., V*, pebble count) are not currently available for PL lands. PL may wish to incorporate those parameters into their monitoring program for future indication of sediment conditions and effectiveness of management actions. Ideally, additional research and monitoring data form Northern California will provide information from which to derive watershed-specific target conditions.

Watershed Analysis and Interim Targets: Given the natural variation in sediment loading between and within watersheds, a watershed inventory and analysis should determine existing sediment levels and identify reasonable interim targets, timeframes and management actions necessary to achieve long-term goals. A watershed analysis including some form of sediment budget, should clearly define baseline conditions and identify relative contributions of sediment from different natural ad human-induced sources (e.g., mass wasting, surface erosion, roads, in-channel storage, etc.).

Biological impact/concern	Parameter	Numerie or narrative target	Reference	Recommended Method	Sampling locations
Decrease in embryo survival due to reduction in gravel permeability, pore space and dissolved oxygen	%fines < 0.85 mm	<11 – 16%	Based on research described in Peterson et al. (1992) for TFW, Chapman (1988) and Burns (1970) baseline data from S. Fork Yager	Valentine Protocols (1995) using McNeil core samplers	Pool/riffle breaks, <3% gradient
Entrapment of fry emerging from redds	%particles <6.35 mm	<20 – 25% (Steelhead and Chinook)	Bjornn and Reiser (1991), McCuddin (1977)	same	same
Measure of spawning gravel quality	Geometric Mean Diameter	>20mm	Shirazi and Seim (1977)	Shirazi and Seim (1977)	n/a
Measure of pore size and permeability of spawning gravel	Fredle Index	>9 (coho)	Lotspeich and Everest (1981)	Lotspeich and Everest (1981)	n/a
Measure of rearing/adult holding habitat in pools	V*	<20%	Knopp (1993)	Lisle and Hilton (1992)	3rd order, <3% gradient streams
Measure of substrate rearing habitat quality	Pebble count (D50)	65-95 mm	Knopp (1993)	Knopp (1993)	same

Biological impact/concern	Parameter	Numerie or narrative target	Reference	Recommended Method	Sampling locations
Suspended sediment potentially impacts migrating juvenile/adult salmon	Turbidity	No visible increase in turbidity due to timber operations in Class I, II, & III watercourses and inside ditches that discharge directly to watercourses.	Modified from Road Use Mitigation Memo by PL (May 20, 1996)		Class I, II, III watercourses and inside ditches that discharge directly to watercourses.
Measure of scour and fill of streambed sediments impacting incubation	Scour Chains	Trend toward less deposition	Nawa and Frissell (1993)	Nawa and Frissell (1993)	low gradient, low confinement
Hillslope sediment delivery mechanisms	Surface erosion and mass wasting from management activities	Zero net discharge of sediment in non-303(d) listed waterbodies Net decrease in sediment delivery from management activities in 303(d) listed waterbodies (Numeric goals to be determined)			
Benthic macroinvertebrate production and diversity	Macroinvertebrate population and/or diversity indices	To be determined	U.S. EPA Rapid Bioassessment Protocols as adjusted by CA DFG		

References:

Bjorn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19: 83-138.

Burns, James 1970. Spawning bed sedimentation studies in northern California streams. Inland Fisheries Division, Calif. Dept. Fish and Game.

Chapman, D.W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society. Vol. 117, No. 1.

Knopp, Christopher 1993. Testing indices of cold water fish habitat. North Coast Regional Water Quality Control Board in cooperation with the California Department of Forestry and Fire Protection.

Lotspeich, F. B. and F. H. Everest 1981. A new method for reporting and interpreting textural composition of spawning gravel. U.S. Forest Service Research Note PNW-139.

McCuddin, Micheal 1977. Survival of salmon and trout embryos and fry in gravel-sand mixtures. Master's Thesis. University of Idaho, Moscow.

Peterson, N.P., A. Hendry and T.P. Quinn 1992. Assessment of cumulative effects on salmonid habitat: some suggested parameters and target conditions. Prepared for the Washington Department of Natural Resources and The Cooperative Monitoring. Evaluation and Research Committee Timber/Fish/Wildlife Agreement. University of Washington, Seattle,Washington.

Shirazi, M.A., W.K. Seim and D.H. Lewis 1981. Characterization of spawning gravel and stream system evaluation. Pages 227-278 in Proceedings from the conference on salmon spawning gravel: a renewable resource in the Pacific Northwest. Washington State University, Washington Water Research Center Report 39, Pullman. Originally published as EPA Report EPA-800/3-79-109.

Valentine Bradley 1993. Stream substrate quality for salmonids: guidelines for sampling, processing, and analysis. California Department of Forestry and Fire Protection, Santa Rosa, CA.

Attachment "C"
Properly Functioning Condition for Large Woody Debris, Including "Key Pieces"

Relationship between channel width and mean for debris diameter, length and volume and the number of pieces of debris in old-growth Douglas-fir forest stream (from Bilby and Ward 1989; Fox 1994)

Channel Width (feet)	Bilby and Ward				Fox "Key Pieces"/5			
	Debris per 100 feet (1)	Geometric mean debris diameter (inches) (2)	Geometric mean debris length (feet) (3)	Mean debris piece volume (cubic feet) (4)	Debris per 100 feet	Average debris diameter (inches)	Average length (feet)	Average debris piece volume (cubic feet)
15	16	14	18	13	3.3	16	27	35.3
20	12	16	20	26	2.5			
25	9	17	22	38	2.0	22	32	88.3
30	7	18	25	51	1.7			
35	6	19	27	63	1.4			
40	5	21	29	72	1.2	25	59	211.9
45	5	22	31	88	1.1			
50	4	23	33	100	1.0			
55	4	25	35	113	1.0	28	78	317.8
60	3	26	37	125	0.8			
65	3	27	40	137	0.8			

1/ Log_{10} debris frequency/100ft=1.12*($\log_{10}$ channel width in feet*0.3048) + 0.46*0.3048*100
2/ Geometric mean diameter (in.) = [2.14(channel width in feet*0.3048)+26.43]/2.54
3/ Geometric mean length (ft.) = [0.43*(channel width in feet*0.3048)+3.55]*3.281
4/ Mean debris piece volume (cu.ft) = [0.23(channel width in feet*0.3048)-0.67]*$(3.281)^3$
5/ A "key piece" is defined as:

"…a log/and or root-wad that:

1) is independently stable in the stream bankfull width (not functionally held by another factor, i.e. pinned by another log, buried, trapped against a rock or bedform, etc.): and
2) is retaining (or has the potential to retain) other pieces of organic debris. Without this "Key piece", the retained organic debris will likely become mobilized in a high flow (approximately a >= 10-year event) (Fox 1994)"

References and notes

Bilby, R.E. and J.W. Ward 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. Transactions of the American Fisheries Society. 118: 368-378.

Fox, Martin 1994. Draft revisions of the WSA Fish Module Diagnostic Matrix: LWD assessment. Muckleshoot Indian Tribe Fisheries Department dated June 6, 1994.

Attachment "D"
Properly Functioning Conditions for Pool Habitat

<u>Purpose of table</u>: Identify properly functioning pool habitat conditions that will provide juvenile rearing habitat, adult holding habitat, and, potentially, thermal and velocity refugia, during all seasons of freshwater residency.
<u>Approach for achieving goals</u>: Watershed analysis should determine existing pool habitat quantity and quality and the distribution of good pool habitat and its spatial relationship to key thermal refugia and spawning areas.

Biological impact/concern	Parameter	Numeric or narrative target	Reference(s)	Recommended Method	Sampling locations
Loss of pool quantity: Loss of juvenile rearing habitat: Juveniles leave stream systems at smaller sizes/younger ages and are subject to greater mortality expressed by smaller return ratios. Loss of adult holding habitat: Deep pools that provide holding habitat particularly escape cover and resting areas for adults of runs that enter streams during low flows and mature in fresh water are lost, thus fewer, or none, of those adults, reproduce successfully	Number of pools per mile equivalent to pool to pool spacing based on bfs widths Percent of stream surface area comprised of pool habitat Percent of number of pools associated with LWD Number of pools per mile equivalent to pool to pool spacing based on dfs widths	In streams with gradients >=3% and average widths < 10 meters (based on Little Lost Man Creek). Pool to pool spacing 1 pool per every 3 bfs channel widths on average (a/), pool area >=20% of the total stream surface area, and >=90% of the # of pools associated with LWD In streams with average gradient <3% and average widths <=19 meters (based on Prairie Creek). Pool to pool spacing 1 pool per every 6 channel widths on average (b/).	Keller et al. 1995 a/Grant et al. In press a/Nakamura and Swanson 1993 Keller et al. 1995 b/Leopold et al. 1964 b/Keller and Melhorn 1978 b/Nakamura and Swanson 1993	Measure distance from point of maximum depth to point of maximum depth.	Response reaches in conjunction with sediment and water temperature. Probably downstream of tributary confluences (Klein 19[] Advances in Hydro-Science and Engineering, Vol 1, Wang (ed)).

	Percent of stream surface area comprised of pool habitat Percent of number of pools associated with LWD	pool area >=25% of the total stream surface area, 50% of the stream surface area composed of pool habitat (c/) 50% of the # of pools associated with LWD	Peterson et al. 1992		
Loss of summer refugia: Fish experience increased predation and potentially thermal stress resulting n decreased rates of survival. Loss of winter refugia: Fish that can not escape from high velocites during high winter flows can be flushed from the system resulting in smaller return ratios, higher mortality from stress (turbidity, starvation) can occur	Maximum depth Volume Cover	>=3 feet maximum depth, V*--(see sediment table) The assumption is made that if LWD levels, bank stability, and riparian stand conditions are met, cover will be adequate	Platts 1983,	Residual maximum pool depth during summer flows.	same

Notes:

Beschta, R.L. and W.S. Platts. 1986. Morphological features of small streams: Significance and function. Water Resources Bulletin, Volume 22, no. 3 P. 360-378.

- Primary and secondary pools…a variety is needed for various age-classes
- Nearly 90% of the pool-riffle sequences may consist of channel reaches 3 to 9 channel widths in length.
- Thus the size, frequency, distribution, and quality of pools in a stream depend on the mechanisms of formation and other characteristics such as size of channel substrates, erodability of banks, and depth of flow.

Grant, Swanson, and Wolman (GSA Bulletin manuscript in review)

- Richards (1978 a, b) and Milne (1982a) corroborated that pool-to-pool spacing is a function of channel width.
- The frequency distribution of pool-to-pool spacing in boulder bedded streams peaked between 2-4 active channel widths, though some streams had bimodal distribution with a primary peak at three and a secondary peak at 6 (with a range as high as 45).
- Church and Gilbert (1975) observed that small streams and torrents seemed to have dominant wavelengths of 2-3.5 times the channel width.
- Milne (1982 a) noted that bed form spacings can easily be upset by variation in sediment mixtures and the presence of 'residual' bedload…which disallowed the high bed-transport rates that produce regular repealing distances.
- Field observations suggest that distinct channel units do not form where sediment supply is high and channels are wide. Instead, braiding occurs and channel bed morphology is characterized by long, featureless rapids (Fahnestock, 1963; Ikeda, 1975).

Keller, E.A., A. MacDonald, T. Tally, and N.J. Merrit. 1995. Effects of large organic debris on channel morphology and sediment storage in selected tributaries of Redwood Creek, northwestern California. IN Geomorphic processes and aquatic habitat in the Redwood Creek basin, northwestern California. U.S. Geological Survey Professional Paper 1454. Nolan, K.M., H.M. Kelsey, and D.C. Marron, (ed.s). U.S. Gov. Print. Office, Washington.

Keller, E.A. and W.N. Melhorn. 1978. Rhythmic spacing and origin of pools and riffles. Geo. Soc. of Am. Bul. V.89, p. 723-730.

- 70% of the variability of spacing in pools can be explained by variability in channel width.
- Alluvial and bedrock channels in different climates had pool spacing that was statistically from the same population.
- Pool to pool spacing is determined by measuring the distance between the maximum depths of adjacent pools.
- Channel width is measured at a point on the riffle between pools where the cross-channel profile is nearly symmetrical and the banks well defined, and is delineated by the width of bed material or the distance between major breaks in slope from the bottom of the channel to the banks of the channel.
- The average spacing is six times the channel width…the conclusion of Leopold and others (1964) that pools are spaced approximately five to seven times the channel width.

Peterson, N.P., A. Hendry, and Dr. T.P. Quinn. 1992. Assessment of cumulative effects on salmonid habitat: Some suggested parameters and target conditions. Prepared for the Washington Dept. of Natural Resources and the Cooperative Monitoring, Evaluation and Research Committee Timber/Fish/Wildlife Agreement. TFW-F3-92-001. Center for streamside Studies, UW, Seattle, WA 98195.

Nakamura, F., and F.J. Swanson. 1993. Effects of coarse woody debris on morphology and sediment storage of a mountain stream system in western Oregon. Earth Surf. Proc. and Landf. v.18, p. 43-61.

[see also: Elser 1968, Lewis 1969]

Properly Functioning Condition for Riparian Forests and Buffer

Purpose of table: Identify properly functioning riparian zone conditions relative to producing targeted levels of large woody debris, maintaining targeted temperature regimes, mitigating potential sediment effects from materials delivered through overland flow and bank cutting, and late-successional forest habitat. The latter includes retention of key habitat elements, including large snags, large woody debris on the forest floor and large sized trees.

Approach for achieving foals: Watershed analysis should determine existing riparian zone stand structure and composition as well as potential to provide key watershed inputs including large woody debris, stream-bank stability and to function in maintaining targeted temperature regimes and late-successional forest habitat structure and composition.

Biological impact/concern	Parameter	Numeric or narrative target	Reference(s)	Recommended Method	Sampling locations
Low large woody debris (LWD) recruitment potential	Quadratic mean tree diameter (QMD) (/1) of fully-stocked stands	>=24 in. dbh <u>or</u> >= targeted ave. "key piece" LWD diameter (/2), whichever is greater	Bilby and Ward 1989. Ca. Board of Forestry 1997, Fox 1994	USDA Forest Service 1995	distal to outer margin of channel migration zone (/3)
	Ave. number of large trees per acre by dbh class	<u>Redwood</u>: 23.8 > 32 in. per acre 17.4 > 40 in. per acre	Redwood (SAF type 232)	same	same
		<u>Douglas-fir</u>: (/x) 18.5, 16.3 > 30 in. per acre 11.0, 9.0 > 40 in. per acre	Douglas-fir/mixed evergreen (SAF Type 234)		
High mid- to late-summer water temperature regimes	Overstory tree canopy closure	Ave. of at least 85 percent overstory tree canopy closure (/4)	Flosi and Reynolds 1994	USAD Forest Service 1995; Ganey and Block 1994	same, assessed for every 200-ft section of riparian zone, on each side of stream

Biological impact/concern	Parameter	Numeric or narrative target	Reference(s)	Recommended Method	Sampling locations
Maintain large downed woody debris for near-stream habitat complexity and filter strip function	a) Ave. tons of large organic debris per acre;	a) redwood: to be determined from samples of old-growth redwood forest riparian zones Douglas-fir: 24.2 tones per acre of materials greater than 10 inches on small end	Jimerson et al. 1996 [Doug-Fir]	USDA Forest Service 1995	distal to outer margin of channel migration zone
		b)			
	b) Ave. number of large pieces of wood on ground per acre	c) redwood: to be determined from samples of old-growth redwood forest riparian zones Douglas-fir: > 30” 3.8 >20” & <30” 6.9 >15” & <20” 6.3 >10” & >15” 12.7	Jimerson et al. 1996 [Doug-Fir]		
	c) percent surface cover and undisturbed area	c) at least 95 percent	Ca. Board of Forestry 1997 Hillslope Monitoring Study ’96 (CDF)		

Biological impact/concern	Parameter	Numeric or narrative target	Reference(s)	Recommended Method	Sampling locations
Maintain large snags for near-stream habitat complexity and to supplement potential LWD	Snags per acre >=30 in. dbh	Ave. of at least three snags per acre >=30 in. dbh (/5)	Richter 1993	same	same, assessed over at most 10 acres of riparian zone (/6)
Loss of vegetative cover and sediment effects from stream bank erosion	Stream bank stability	"Good" to "Excellent" stream bank stability afforded by root systems of large trees supplemented by large wood and shrub layer	Pfankuch, 1978	Pfankuch, 1978	Lower and upper banks (Pfankuch 1978) and channel migration zone

/1 Only trees > 5 in. dbh are included in QMD calculations. Confidence interval of ± 5 percent at 95 percent.
/2 See tables under "Targeted Conditions for Large Woody Debris."
/3 See channel migration zone definition in "Aquatic Conservation Strategy" (USDA and USDI 1994, "Record of decision.")
4/ Increase to greater than 90 percent where temperature regimes do not meet the criteria for "properly functioning."
5/ Assuming a 100-foot-wide zone on both sides, this would be equivalent to >=1.4 large snags of this size per 100 feet of stream.
6/ Assuming a 100-foot-wide zone, this would be equivalent to an assessment per 0.8 miles of stream.

References

Bilby, R.E. and J.W. Ward 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. Transactions of the American Fisheries Society. 118: 368-378.

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Franklin, Jerry; Kermit Cromack Jr., William Denison, Arthur McKee, Chris Maser, James Sedell, Fred Swanson and Glen Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. U.S.D.A. Forest Services General Technical Report PNW-118, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 48p.

Ganey, Joseph L. and William M. Block 1994. A comparison of two techniques for measuring canopy closure. WJAP 9(1) p.21-23.

Jimerson, T., E. McGee, David W. Jones and others 1996. A field guide to the tanoak and Douglas-fir plant associations in northwestern California. USDA Forest Service Pacific Southwest Region R5-ECOL-TP-009.

Pfankuch, Dale 1978. Stream reach inventory and channel stability evaluation, a watershed management procedure. USDA Forest Service Northern Region R1-75-002. 26p.

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U.S. Department of Agriculture and U.S. Department of Interior 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the Northern Spotted Owl, Attachment A: Standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the Northern Spotted Owl: 74 pages with attachment.

Attachment “F”
Properly functioning Condition for Class III Watercourses

Purpose of table: Identify properly functioning conditions within zones containing class III watercourses. These conditions relate to producing targeted levels of large woody debris for terrestrial species and for delivery to aquatic habitats, mitigating potential sediment effects to class I and II habitats and associated species from sediment delivered through class III watercourses and producing key habitat elements. The latter includes retention and production of large snags, large woody debris on the forest floor and large trees.

Approach for achieving goals: Watershed analysis should determine the existing stand structure and composition of trees, snags and downed woody materials and other elements along class III watercourses, evaluate the risk of sediment effects to aquatic species (including salmonids, salamanders and frogs) from timber operations near class III watercourses, evaluate the potential to provide key watershed inputs including large woody debris, stream-bank stability and to function in maintaining targeted hill slope habitat structure and composition.

Biological impact/concern	Parameter	Numeric or narrative target	Reference(s)	Recommended Method	Sampling locations
Low snag and large woody debris (LWD) recruitment potential	Ave. number of green trees per acre by dbh class	All species: (/1) 3 >11in., <15 in. 3 >15in., <30 in. 3 >30 in.	Bisson et al. 1997, Cline et al. 1980, Freel, 1991, Richter, 1993	USDA Forest Service 1995	within “equipment exclusion zone” (/2)
Maintain large snags for near-stream habitat complexity and to supplement potential LWD	“Soft” and “hard” snags per acre	All species: 1 >11in., <15 in. 1 >15in., <30 in. 1 >30 in.	Cline et al. 1980, Freel, 1991, Richter, 1993	same	same
Maintain large downed woody debris for habitat complexity and filter strip function	a) Ave. tones of large organic debris per acre;	a) redwood: to be determined from samples of old-growth redwood forest Douglas-fir: 24.2 tones per acre of materials greater than 10 inches on small end	Jimerson et al. 1996	USDA Forest Service 1995	within equipment exclusion zone
	b) Ave. number of large pieces of wood on ground per acre	b) redwood: to be determined from samples of old-growth redwood forest riparian zones Douglas-fir: > 30” 3.8 >20” & <30” 6.9 >15” & <20” 6.3 >10” & >15” 12.7	Jimerson et al. 1996		
	c) Percent surface vegetative cover	c) at least 95 percent surface vegetation	Ca. Board of Forestry hill slope monitoring study (/3)		

Biological impact/concern	Parameter	Numeric or narrative target	Reference(s)	Recommended Method	Sampling locations
Loss of vegetative cover and sediemnt effects from stream bank erosion	Stream bank stability	“Good” to “Excelent stream bank stability afforded by root systems of large trees supplemented by large wood and shrub layer	Pfankuch 1978	Pfankuch, 1978	Lower and upper banks (Pfankuch 1978)

1/ This number of trees in each size class would be permanently marked for retention prior to each harvest entry.

2/ Equipment exclusion zones will be established along all class III watercourses. Zone widths will vary according to slope class, silvicultural prescription, yarding method and method of site preparation, slope location (e.g. upslope vs. “inner gorge”) and downstream resources to be protected.

3/ Personal communications from Peter H. Cafferata, California Department of Forestry and Fire Protection, March 3, 1997 and based on information obtained through the Hill slope Monitoring Study funded by the California Board of Forestry.

References

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APPENDIX II Salmon Matrix Review- Related Literature

PART I: MATRIX CITED LITERATURE

1. USDA (Forest Service Research/National Forest System). March 1993. Visibility assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest: The report of the Scientific Analysis Team. Appendix 5-K. pp 427-482

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3. Brungs, W. A., and B. R. Jones. May 1977. Temperature criteria for freshwater fish: Protocol and procedures. Environmental Research Laboratory/ Office of Research and Development/USEPA.

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16. Nawa, R. K., and C. A. Frissell. 1993. Measuring scour and fill of gravel streambeds with scour chains and sliding-bead monitors. North American Journal of Fisheries Management 13: 634-639.

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18. Cline, S. P., Berg, A. B., and H. M. Wight. 1980. Snag characteristics and dynamics in Douglas-fir forests, Western Oregon. Journal of Wildlife Management 44(4): 773-786.

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20. FAX Transmission from Protected Resources Division, NMFS, to Stillwater Sciences. June 11, 1999. 20p.

21. Flosi, G. and F.L. Reynolds. no date. California salmonid stream habitat restoration manual, Second edition. Inland Fisheries Division, Calif Dept. Fish Game, The Resource Agency. pp V21-22.

22. USDA- Forest Service, Pacific Southwest Division. June 1995. Forest inventory and analysis user's guide. USDA/ Forest Service Region 5. partial, total 5p.

23. Jimerson, T. M. et. al. no date A field guide to the Tanoak and the Douglas-fir plan associations in northwestern California. (Partial copy, 2 pages showing log characteristics for seal stages in the Douglas-fir series)

24. Ganey, J. L., and W. M. Block. 1994. A comparison of two techniques for measuring canopy closure. WJAF 9 (1): 21-23.

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26. D. J. Richter, CA Department of Fish and Game. October 1994. Memo to Bill Condon, CA Department of Fish and Game, regarding snag/wildlife tree operational procedures – habitat team assignment. 33p.

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PART II: BACKGROUND MATERIAL

28. Veirs, S. D. 1996. Ecology of the coast redwood, pp. 9-12 IN The proceedings of the conference on coast redwood forest ecology and management, June 18-20, 1996, Humboldt State University, Arcata, CA.

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PART III: OTHER DOCUMENTS

35. Public/Private Comments on Matrix for Pacific Lumber HCP (INCLUDES SEVERAL COMMENTS)

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37. NMFS Environmental and Technical Services/Habitat Conservation Branch. August 1996. Making Endangered Species Act determination of effect for individual or grouped actions at the watershed scale. NMFS. 21p.

38. Habitat Conservation Plan for the Properties of the Pacific Lumber Company, Scotia Pacific Holding Company, and Salmon Creek Corporation, February 1999. iv + pp. 3-70.

APPENDIX IIIa Statement of Work.

STATEMENT OF WORK

Consulting Agreement Between the University of Miami and Larry Marshall

October 20, 2000

General

In March 1997, federal and state agencies developed an aquatic matrix for the Pacific Lumber Company Habitat Conservation Plan (hereafter "salmon matrix"). The matrix puts forth a condition for the landscape which has been determined to be properly functioning in order to meet the habitat needs of anadromous salmonids and other aquatic species in northern California on Pacific Lumber Company properties in Humboldt County.

Consultants shall need to address the following questions for the salmon matrix review:

1. Are the metrics used in the matrix appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs for threatened and candidate salmonid species? If not, which metrics would be appropriate and at what landscape scales?

2. Are the values provided for the metrics appropriate for assessing aquatic and associated riparian habitat condition to meet the needs of threatened and candidate salmonid species in coastal redwood systems? If not, which values would be appropriate and at what landscape scales?

3. Which metrics are the most appropriate for the assessment, monitoring, and adaptive management of aquatic candidate salmonid species in coastal redwood systems?

4. How should in-stream and riparian metrics be functionally and practically linked with upslope and watershed scale processes that, in part, determine their expression?

Specific

The consultant's duties shall not exceed a maximum total of three weeks- several days for document review, a 4-day meeting, and several days to produce a written report of the findings. Please note that the report produced must be based on the consultant's individual opinions of the science in his area of expertise and not that of the group; thus, no consensus report shall be produced.

The itemized tasks of the consultant include:

1. Reading and analyzing the relevant documents provided to the consultant;

2. Participating in a 4-day meeting with the other consultants and NMFS officials in San Francisco/Arcata, CA, from November 27-30;

3. No later than January 15, 2001, submitting a written report of findings, analysis, and conclusions. The report should be addressed to the "UM Independent System for Peer Reviews, " and sent to Dr. David Die, UM/RSMAS, 4600 Rickenbacker Causeway, Miami, FL 33149 (or via email to ddie@rsmas.miami.edu).

Signed___________________________________ Date______________

APPENDIX IIIb Addendum to Statement of Work.

ADDENDUM TO STATEMENT OF WORK

November 22, 2000

This addendum is not to replace the contents of the original statement of work or the questions that the reviewers are to consider. It is, however, meant to clarify some of the questions that the reviewers are to address when conducting the review and completing the review report. Most importantly, the reviewers should consider the two following points:

1. In question 3 on the Statement of Work, reviewers are asked to consider which metrics are most appropriate for the assessment, monitoring, and adaptive management of aquatic candidate salmonid species in coastal redwood systems. The reviewers are to incorporate their findings from question 1, which asks whether the metrics used in the matrix are appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs for threatened and candidate salmonid species, and if not, then which metrics would be appropriate and at what landscape scale. These findings from question 1 may provide a subset of metrics that are appropriate for the specific habitats in coastal redwood systems. If there are other metrics that are more appropriate and not used in the matrix, the reviewers may address these as well.

2. In addition to question 4 on the Statement of Work, the following question may assist the reviewers on addressing the applicability of the matrix framework:

   Does the matrix framework provide adequate tools and guidelines for stream and riparian metrics to be functionally and practically linked with upslope and watershed scale processes that, in part, determine their expression? If not, what additional features, properties, or guidelines should be addressed to the matrix framework?

APPENDIX IV Additional Information Resources.

Additional Information Resources

*Ethan Bell:
Fish Biologist
Current Work:
Coho rearing habitat utilization and over winter growth
Stillwater Sciences
(707) 822-9607; ethan@stillwatersci.com

Greg Blomstrom:
Forester
Current Work:
Planning Forester
Forestry Division, Hoopa Valley Tribe
(916) 625-4284; GregB@PCWeb.net

*Greg Bryant:
Fish Biologist
Current Work:
Salmon Recovery Coordination
National Marine Fisheries Service, Protected Resources Division, Arcata
(707) 825-5162; Greg.Bryant@noaa.gov

*John Clancy:
Fish Biologist
Current Work:
PALCO HCP implementation
National Marine Fisheries Service, Protected Resources Division, Arcata
(707) 825-8175; John.P.Clancy@noaa.gov

*Bill Condon:
Forester
Original HCP negotiator and Matrix development
Current Work:
PALCO HCP implementation
California Department of Fish and Game, Eureka
(707) 441-2064; wcondon@dfg.ca.gov

Scott Downie:
Fish Biologist
Current Work:
Habitat mapping Eel River drainage
California Department of Fish and Game, Inland Fisheries Division, Fortuna
(707) 725-1070; fdownie@dfg2.ca.gov

Jim Falls:
Geologist
Current Work:
Watershed Analysis
Landslide mapping
Department of Conversation, Division of Mines and Geology
(707) 441-3511; JFalls@consrv.ca.gov

*Sam Flanagan:
Geologist
Current Work:
Watershed analysis, HCP negotiation
National Marine Fisheries Service, Protected Resources Division, Arcata
(707) 825-5173; Sam.Flanagan@noaa.gov

Dan Free:
Fish Biologist
Current Work:
Has History of hatchery programs
PL HCP Implementation
National Marine Fisheries Service, Protected Resources Division, Arcata
(707) 825-5164; Dan.Free@noaa.gov

David Fuller:
Fish Biologist
(Contact for Headwaters Forest Preserve)
Bureau of Land Management, Arcata
(707) 825-2300; dfuller@ca.blm.gov

*Danny Hagens
Geologist
Current Work:
Sediment Source Inventories
Forest Road Design
Pacific Watershed Associates
(707) 839-5130;

Dave Hankin:
Professor, Fish Biologist
Current Work:
Life history and harvest policies for Chinook salmon;
Survey designs in small streams
Humboldt State University, Fisheries Department
(707) 826-3447; dgh1@axe.humboldt.edu

Bret Harvey:
Research Fisheries Biologist
Current Work:
Salmonid habitat, evaluation, use and distribution
Forest Service, PSW Research Station, Redwood Sciences Lab

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*Mathew R. House:
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*Randy Klein:
Hydrologist
Current Work:
Fluvial processes, hydrology, role of LWD
Redwood National Park
(707) 825-5111; randy_klein@nps.gov

*Sharon Kramer:
Fish Biologist
Current Work:
Conservation biology and ecology of anadromous salmonids and their habitat
Role of LWD
Stillwater Sciences
(707) 822-9607; sharon@stillwatersci.com

Andre Lehre:
Professor, Geologist
Current Work:
Geomorphology, hydrology, hillslope processes, fluvial processes
Humboldt State University, Geology Department
(707) 826-3165; akl1@axe.humboldt.edu

Tom Lisle:
Hydrologist
Current Work:
Fluvial processes, role of LWD
Forest Service, PSW Research Station, Redwood Sciences Lab,
(707) 825-2901; tlisle@fs.fed.us

*Maryann Madej:
Geologist
USGS/BRD
(707) 825-5645; mary_ann_madej@usgs.gov

*Leslie Reid:
Geologist
Current Work:
Geomorphology, hillslope processes, fluvial processes
Evaluation of the impact of timber operations on a landscape scale
Forest Service, PSW Research Station, Redwood Sciences Lab
(707) 825-2933; lmr7001@axe.humboldt.edu

Terry Roelofs:

Professor, Fish Biologist

Current Work:

Conservation biology and ecology of anadromous salmonids and their habitat;
Watershed restoration

Humboldt State University, Fisheries Department

(707) 826-3344; tdr1@axe.humboldt.edu

*Bill Trush:

Fish Biologist/Fluvial Geomorphologist

Current Work:

Environmental Impacts of Dams on River Ecosystems,
Effects of Timber Harvesting on Stream Channel Morphology,
Anadromous Fish Life History,
Fish Passage through Culvert Systems,
Large Scale Restoration of Central Valley Streams,

McBain and Trush Consulting

(707) 826-7794; McBTrush@northcoast.com

*Margaret Tauzer:

Hydrologist

Current Work:

Evaluation of artificial flow regime

National Marine Fisheries Service, Protected Resources Division, Arcata

(707) 825-5174; Margaret.Tauzer@noaa.gov

Hartwell Welsh:

Research Wildlife Biologist

Current Work:

Determination of management thresholds for impaired cold-water adapted fauna.

Forest Service, PSW Research Station, Redwood Sciences Lab

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Leslie Wolff:

Hydrologist

Current Work:

Evaluation of gravel extraction
Timber harvest plan review

National Marine Fisheries Service, Protected Resources Division, Arcata

(707) 825-5172; Leslie.Wolff@noaa.gov

Bob Ziemer:

Chief Research Hydrologist, Director, Redwood Sciences Laboratory

Current Work:

Hydrology and fluvial processes

Forest Service, PSW Research Station, Redwood Sciences Lab

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APPENDIX V Salmon Matrix Review-Related Literature.

SALMON MATRIX REVIEW-RELATED LITERATURE

PART I: LITERATURE PROVIDED/ REQUESTED IN ARCATA

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51. USFWS. 1999. Coho considerations, proposed rule language. [from July 6, 1999]. 20 p.

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PART II. ADDITIONAL READING

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56. Bisson, P.A., G.H. Reeves, R.E. Bilby, and R. J. Naiman. 1997. Watershed management and Pacific salmon: desired future conditions. pp 447-474 IN Stouder, D.J., P.A. Bisson, R.J. Naimen [eds].Pacific salmon and their ecosystems: status and future options, Chapman & Hall, New York. 685 p.

57. Bradford, M.J. 1997. Empirical review of coho salmon smolt abundance and the prediction of smolt production at the regional level. Trans. Amer. Fish. Soc. 126: 49-64.

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59. Harvey, B.C.,. R.J. Nakamoto, and J.L. White. 1999. Influence of large woody debris and a bankfull flood on movement of adult resident coastal cutthroat trout (*Oncorhynchus clarki*) during fall and winter. Can. J. Fish. Aquat. Sci. 56: 2161-2166.

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